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AN UNNECESSARY CONTROVERSY

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Evidence of the interest in circuit conventions and phasor diagrams during the last ten years can be seen in the publication in this journal[1] and in *Electronics & Power*[2] of a number of articles thereon and, in the latter journal, of more than 50 letters. Arising mainly from this the writer has opened discussions in various IEE centres.

A prevailing state of mutual incomprehension on even the simplest aspects of the subject led to a progressive narrowing of the field of inquiry until it comprised no more than Fig. 1. It may seem hard to believe that those engaged in teaching the principles of a.c. circuits at university and technical college levels would not only contradict one another on how to deal with such an uncomplicated circuit but would have difficulty in seeing wherein their disagreements lay. Yet so it was on at least some of the occasions referred to. If this state of affairs is at all typical it can hardly be in the best interests of electrical engineering education, so an attempt to trace the root of the trouble may not appear superfluous.

Although there are many subdivisions on points of detail, two main schools of thought can be distinguished: (i) those who represent the sinusoidal generator e.m.f. and the e.m.f. of self induction by oppositely pointing phasors, and (ii) those who show them in phase. It is remarkable how exasperated it is possible for either to get when arguing with the other. Both claim that the physical facts are on their side. Nevertheless it is, as will have been guessed, a matter of convention. And in such there is no wrong nor right. Yet it is not on that account unworthy of serious

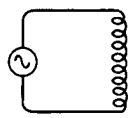

FIG. 1 This circuit, deceptively simple, gives rise to stern controversy.

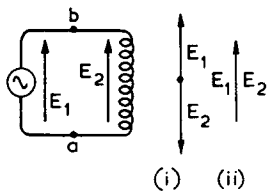

FIG. 2 When phasor diagrams are asked for, two opposite alternatives emerge.

consideration. The present diversity of conventions in this field is not only in itself untidy but it can cause such mental confusion that mistakes about physical behaviour result[3].

In spite of the fact that books in which symbols for the voltages in circuits are accompanied by two-way arrows, giving 100% ambiguity, continue to be published, let us ignore this practice from the start since it offers no basis for rational discussion. There remain several reasonable conventions for e.m.fs in circuit and phasor diagrams[4], of which those used in Fig. 2 will at least be familiar. Supporters of phasor diagram (i) argue that there undeniably is a physical e.m.f. E_2 which is equal *and opposite* to E_1 and therefore obviously must be so represented, while partisans for (ii) hold with equal tenacity that there can be only one p.d. at a time between any two points (a and b in this case) and that it is therefore sheer perversity not to see that E_1 and E_2 must be shown in phase.

So far, (i) seems to have rather the more convincing case, which may account for advocates of it being apparently in a considerable majority. Their opponents are in no way discouraged however, and proceed to add a second similar loss-free inductor in parallel (Fig. 3) and then invite those on the other side to deal with it after their manner. The confidence of those invited thereupon begins to ebb, for they see that whichever way they draw the phasor for E_3 they will find that way difficult to defend. After a little hesitation the choice will probably be as shown. Those who so choose will then be required to explain why they treat E_1 and E_2 according to method (i) and E_2 and E_3 according to method (ii). (The opposite choice is at least equally open to the same kind of attack).

The answer to this will no doubt be that although E_1, E_2 and E_3 are all e.m.fs E_1 is different in kind because it is the originating one, and when current is brought into the matter E_2 and E_3 will be against the current, which is driven by E_1; hence the difference in treatment in the phasor diagram. Their opponents will not be slow to point out that in fact all three e.m.fs are equally in quadrature with the current, and although in this ideally simple circuit the generator and load roles are clearly seen, in more complicated situations these may be precisely what one has to find out; they cannot be assumed to be given. Would it not be better to use conventions that make no such assumptions?

The more honest and open-minded advocates of (i) would admit there was some merit in these arguments. But unfortunately it seems to be a fact of life that having become accustomed to certain conventions one defends them to the death rather than consider an alternative on its merits. And what about the physical facts, which are claimed by both sides contradictorily?

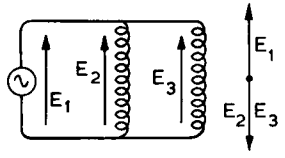

FIG. 3 This slightly augmented circuit faces upholders of Fig. 2(i) with a dilemma.

Although the explanation of this dilemma may seem obvious when pointed out, in the heat of battle it usually escapes notice. Proponents of (i) can show quite conclusively from Lenz's law that E_1 and E_2 are in phase opposition *when referred to the current.* Those who favour (ii), on the contrary, refer their voltages to the points between which they exist.

Once that is realized, the dispute shifts to justifying the choice of references. Here, the (ii) side can argue that their choice does not have to bring current into the question at all, so is simpler. And circuit nodes are inherently more appropriate for voltages, just as meshes are for currents. We can see now that the essence of the contradiction is that side (ii) considers both E_1 and E_2 from a to b, so both are positive together and therefore in phase, whereas side (i) has an eye on the current which goes from a to b for one half of the circuit and from b to a for the other half, so if E_1 and E_2 are considered from a to b and from b to a respectively they are bound to be opposite in phase. So both contestants are right, so (as the Dodo would have insisted) both must get prizes.

To many readers this whole dispute may seem trivial. But it is less than the tip of the iceberg. It is closely bound up with the philosophy that in accordance with Kirchhoff's voltage law (in its original form, $\Sigma E \equiv \Sigma V$) one must begin by distinguishing between e.m.fs and p.ds. Apart from the fact that which voltages are which may be among the unknowns to be ascertained rather than the data given, the task of distinguishing is one that throws the ranks of those who force it on themselves into disarray, as a careful comparison of current textbooks makes plain. Suffice to say that there is no general agreement on how to set about it[5]. Happier are they who start by treating all as just voltages ($\Sigma V \equiv 0$, the dual of the current law, $\Sigma I \equiv 0$) and let those that are e.m.fs be disclosed by the phasor diagram, constructed according to simple rules.[6]

But the whole controversy is unnecessary, as are the arrow heads that generate it. The convention illustrated in Fig. 4 is clearly simpler than Fig. 2, (i) or (ii). So other things being equal it should be preferred. But things are not at all equal. Unlike Fig. 2, (i) or (ii), Fig. 4 is acceptable by both parties. Indeed there would have been no division into parties if it had been used from the start. For, using it, the facts that V_{ab} is in antiphase to V_{ba} and that V_{ab} is in phase with V_{ab} are self-evident. Both facts are represented impartially by the irreducibly simple phasor diagram. Moreover, as befits an alternating quantity, no one set of half-cycles has arbitrarily been given preference by an arrow head. Can anyone justify the use of arrow heads? If not, why do they continue to be used?

Advocacy of the Fig. 4 convention as a preferred standard has been criticized on

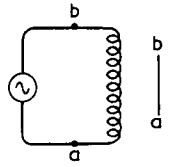

FIG. 4 Using this simpler alternative to either variety of Fig. 2, the controversy does not arise.

the ground that there are valid alternatives capable of good service.[7] But the claim that whatever these alternatives can do, the method exemplified in Fig. 4 can do better (often very much better) does not appear to have been convincingly refuted. One example has just been given of confusions that simply do not arise if the method advocated is used. Is there any merit in retaining alternatives, however valid, which are less simple and which introduce wholly unnecessary diversity and risk of confusion, thereby taking up students' time and thought that could more profitably be devoted to topics of inherent difficulty?

REFERENCES

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[2] Stefani, I. L. *Electronics & Power*, 17, p. 104 (1971). Say, M. G. ibid 15, p. 355 (1969). Scroggie, M. G. ibid 10, p. 47 (1964).

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[4] Stefani, I. L. *Electronics & Power*, 17, p. 104 (1971).

[5] Scroggie, M. G. *Phasor Diagrams* (Iliffe), pp. 129, 130 and 164–173.

[6] Ibid. Chap. 6 and pp. 176, 177.

[7] Gray, C. B. *Electronics & Power*, 11, p. 419 (1965)

ABSTRACTS–ENGLISH, FRENCH, GERMAN, SPANISH

An unnecessary controversy

There is ample evidence of misunderstandings and confusion over conventions relating to even such a simple circuit as a generator feeding a load. The reasons for this are traced and a simple solution offered which harmonizes opposing arguments and renders controversy unnecessary.

Une controverse inutile.

Il est bien évident qu'il existe des incompréhensions et une confusion sur les conventions relatives à un circuit même aussi simple qu'un générateur alimentant une charge. Les raisons de cette confusion sont retraçées et une solution simple est proposée, qui harmonise les arguments et rend inutile toute controverse.

Eine unnötige Kontroverse

Missverstehen und Konfusion im Falle von Konventionen, selbst wenn sich diese auf einfache Stromkreise, wie ein eine Last beliefernder Generator, beziehen, sind häufig. Die Gründe hierfür werden ausfindig gemacht und eine einfache Lösung wird geboten, die entgegengesetzte Argumente aussöhnt und Kontroverse überflüssig macht.

Una controversia innecesaria

Hay una amplia evidencia de que existen errores de interpretación y bastante confusión acerca de las convenciones relacionadas incluso con un circuito tan sencillo como el formado por un generador alimentando una carga. Se determinan las razones de este hecho y se ofrece una sencilla solución que armoniza argumentos opuestos y que hace inútil la controversia.